Superconducting Integrated Receiver Based on Nb-AlN-NbN-Nb Circuits

Mikhail Torgashin, Valery Koshelets, Pavel Dmitriev, Andrey Ermakov, Lyudmila Filippenko

Institute of Radio Engineering and Electronics (IREE), Moscow, Russia

and Pavel Yagoubov

SRON Netherlands Institute for Space Research, the Netherlands

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The Superconducting Integrated Receiver (SIR) comprising in one chip a superconductor-insulator-superconductor (SIS) mixer and a phase-locked superconducting Flux Flow Oscillator (FFO) is under development for the international project TELIS. To overcome temperature constraints and extend operation frequency of the SIR we have developed and studied Nb-AlN-NbN-Nb circuits with a gap voltage Vg up to 3.7 mV and extremely low leakage currents (Rj/Rn > 30). Based on these junctions integrated microcircuits comprising FFO and harmonic mixer have been designed, fabricated and tested; the radiation from such circuits has been measured at frequencies up to 700 GHz. Employment of NbN electrode does not result in the appearance of additional noise. For example, FFO linewidth as low as 1 MHz was measured at 600 GHz, that allows us to phase lock up to 87 % of the emitted by FFO power and realize very low phase noise about –90 dBc. Preliminary results demonstrated uncorrected DSB noise temperature of the Nb-AlN-NbN SIR below 250 K at frequencies around 600 GHz

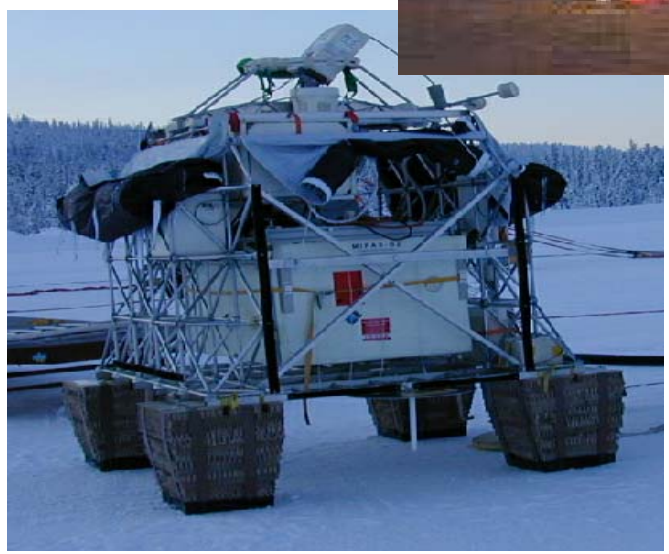
TELIS - TErahertz LImb Sounder

TELIS Objectives:

- Measure many species for atmospheric science (ClO, BrO, O_3, HCl, HOCl, etc);
  - Chemistry, Transport, Climate
- Serve as a test platform for new sensors
- Serve as validation tool for future satellite missions

Three independent frequency channels, cryogenic heterodyne receivers:

- 500 GHz by RAL
- **600-650 GHz by SRON-IREE**
- 1.8 THz by DLR (PI)



Schematics of PLL SIR

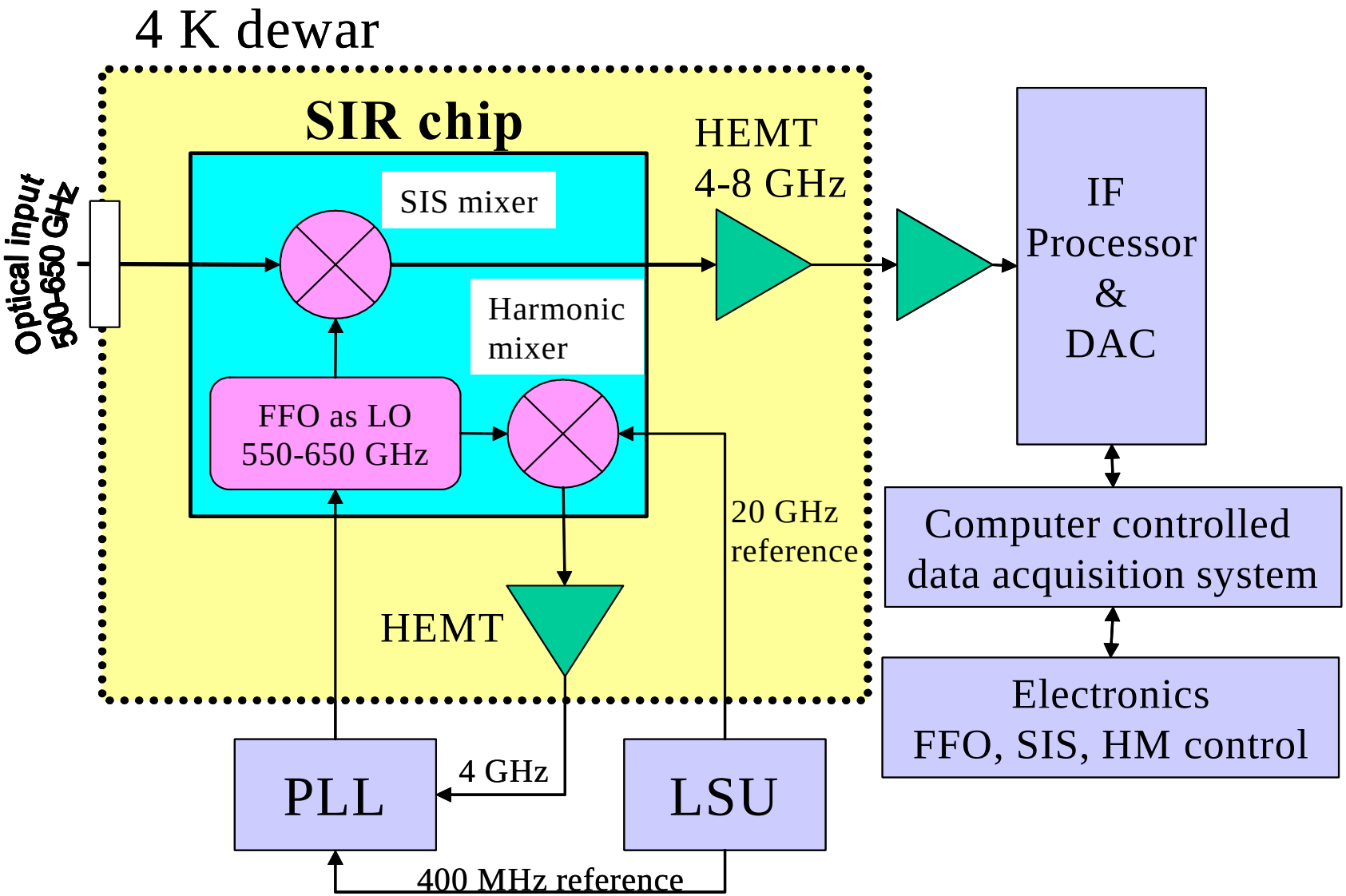
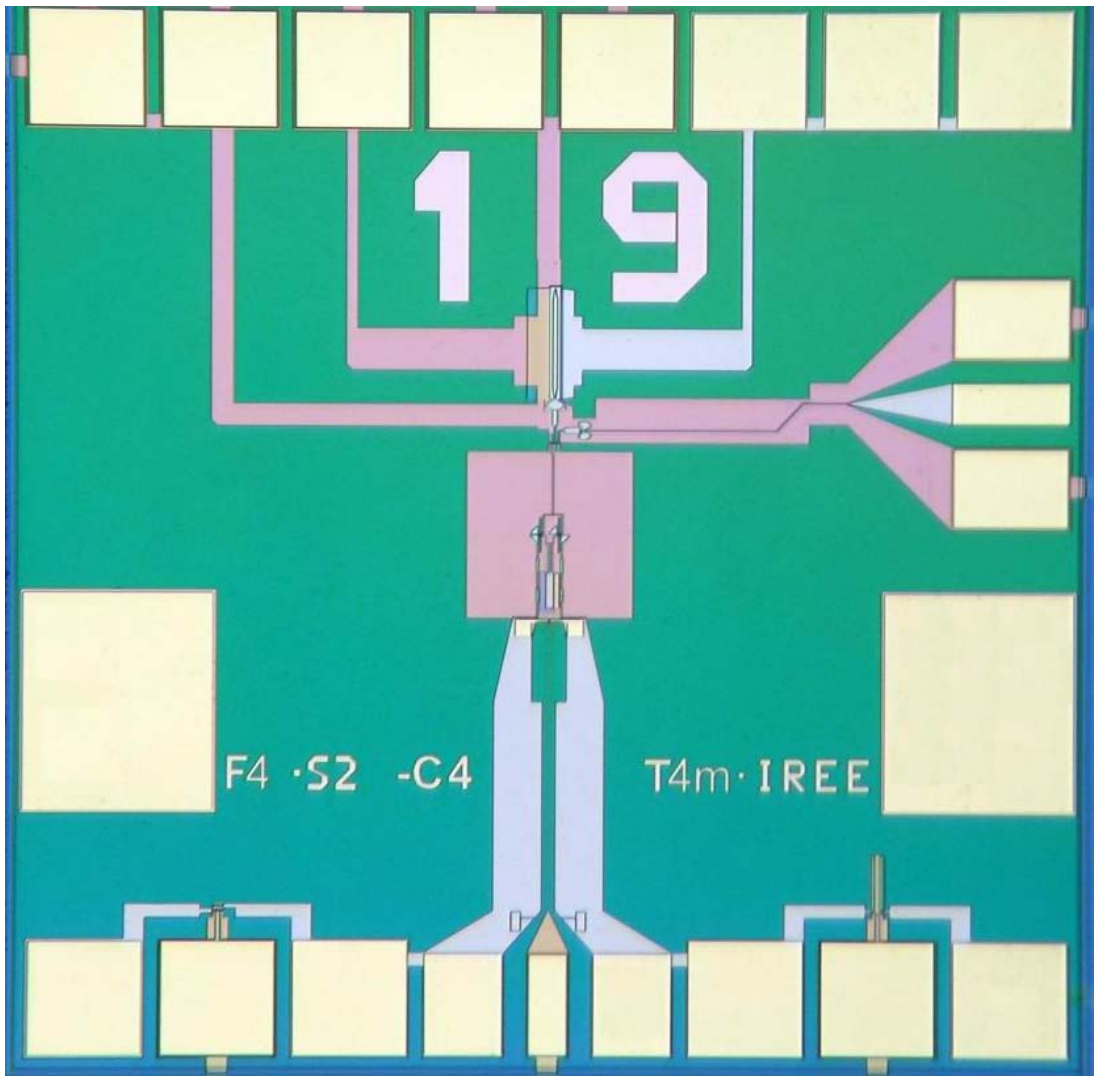
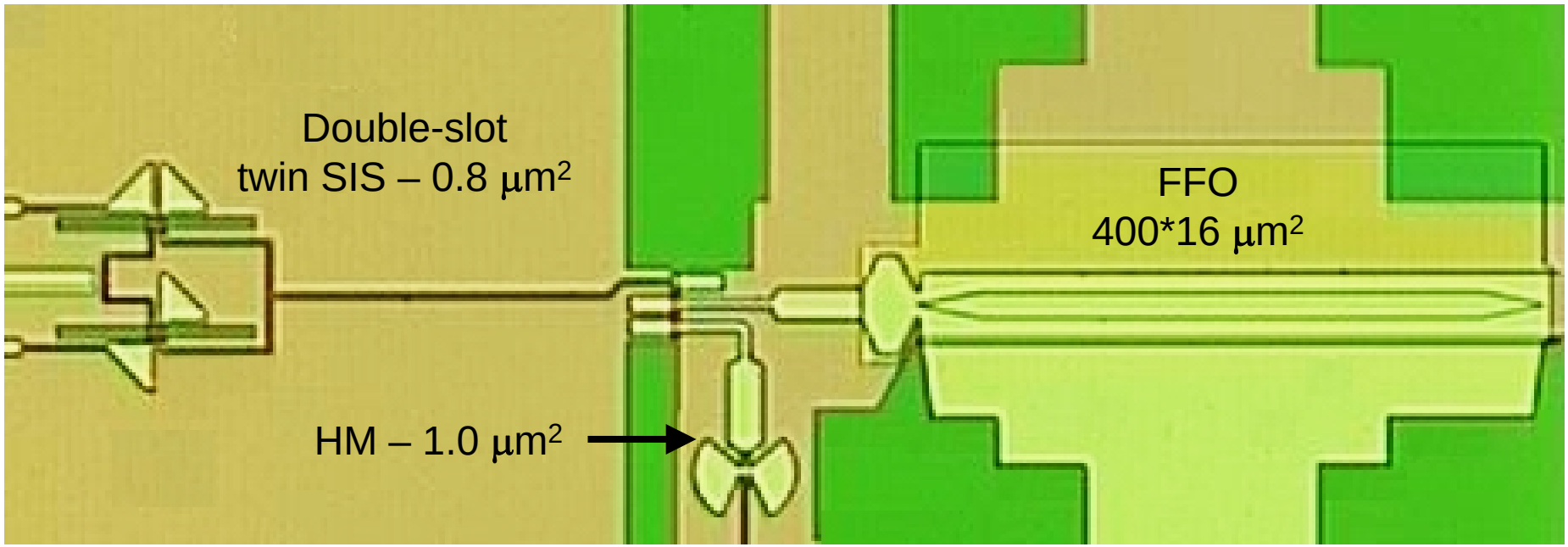


Photo of the T4m SIR chip



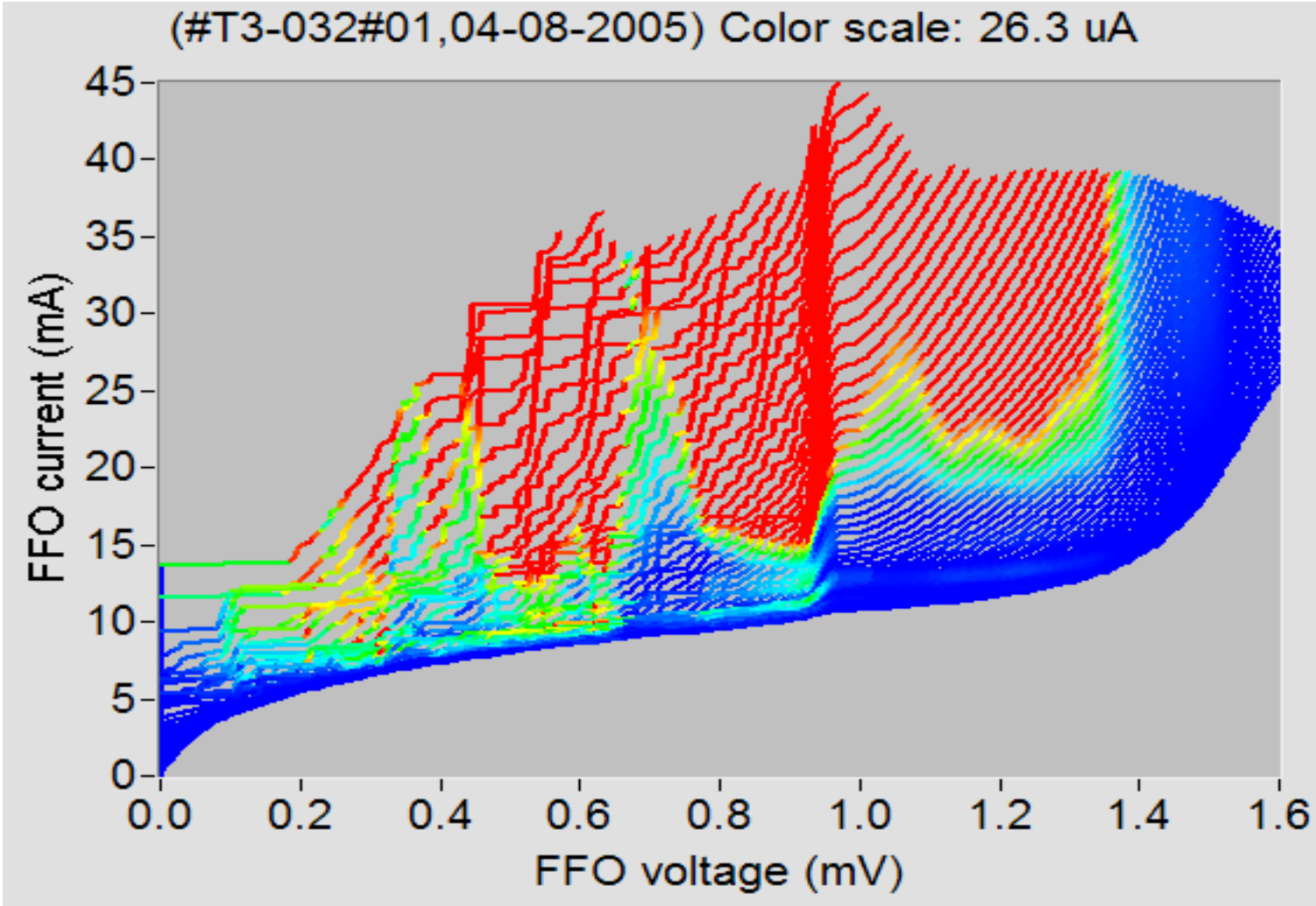
SIR Microcircuit for TELIS



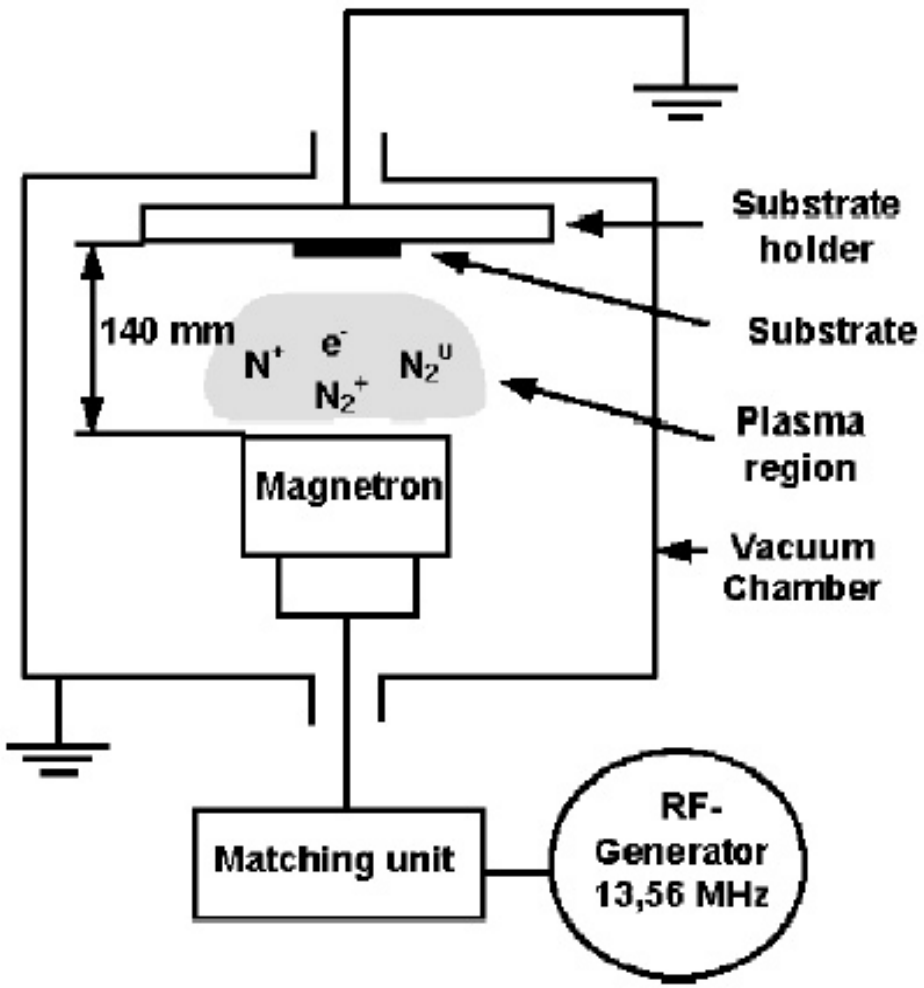
4 x 4 x 0.5 mm³ (Si); Nb-AlOx-Nb; Jc = 5 - 8 kA/cm²

Optionally: SIS – Jc = 8 kA/cm²; FFO + HM = 4 kA/cm²

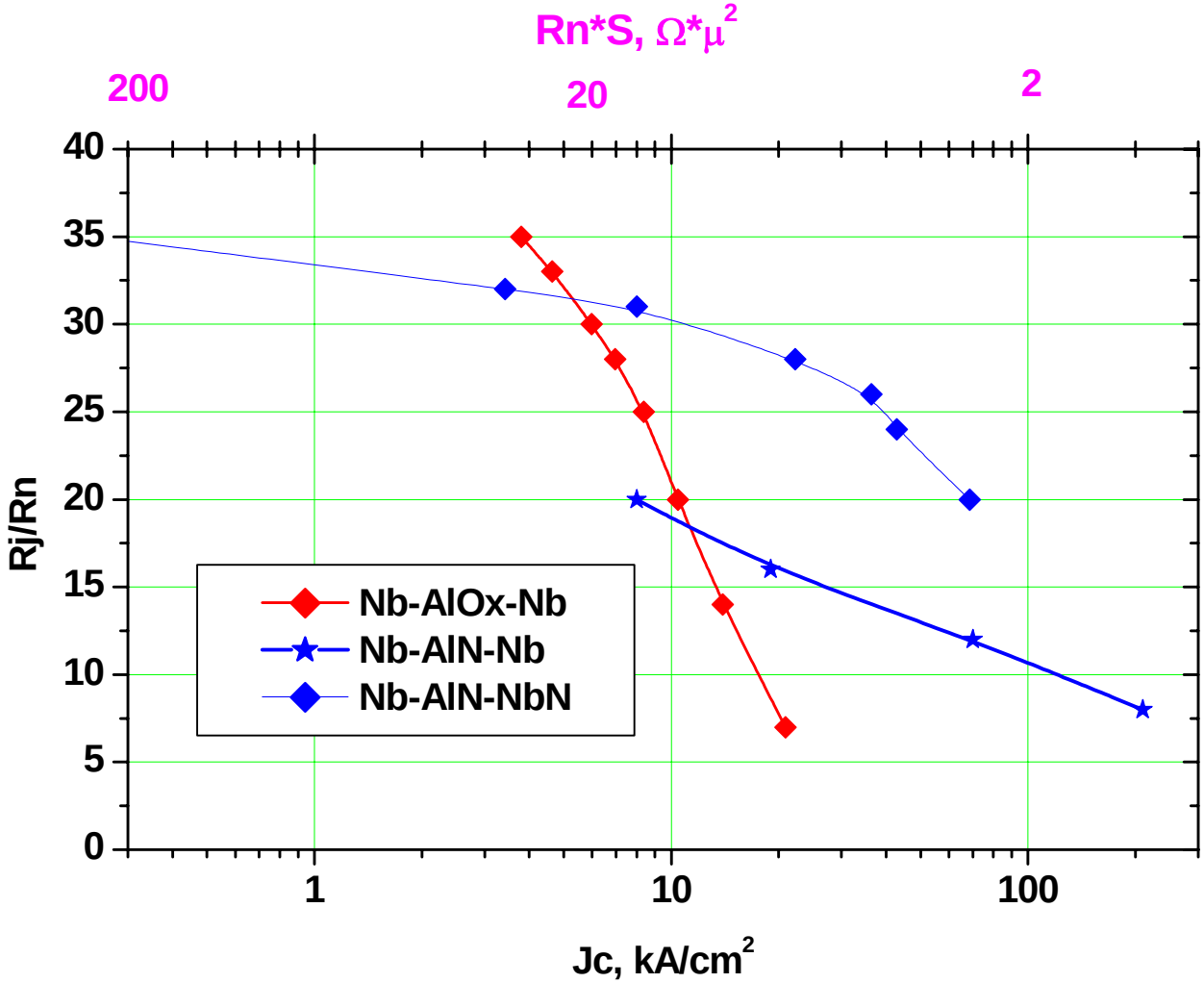
IVCs of the Nb-AlOx-Nb FFO measured at different CL currents (red = > 25% of SIS Ig)



The electrical scheme of the nitridation process

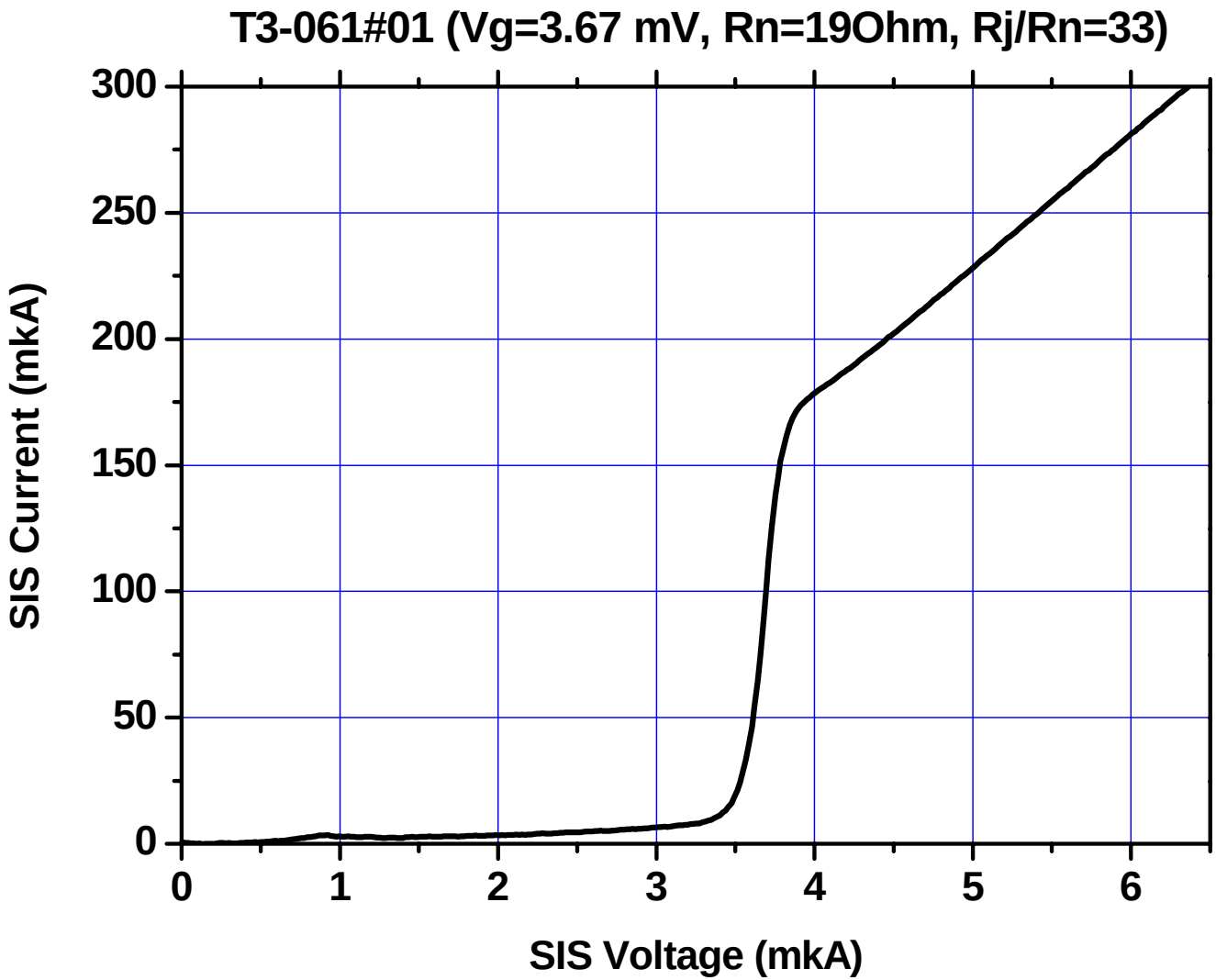


The dependency of Rj/Rn ratio on critical current densities for different types of junctions

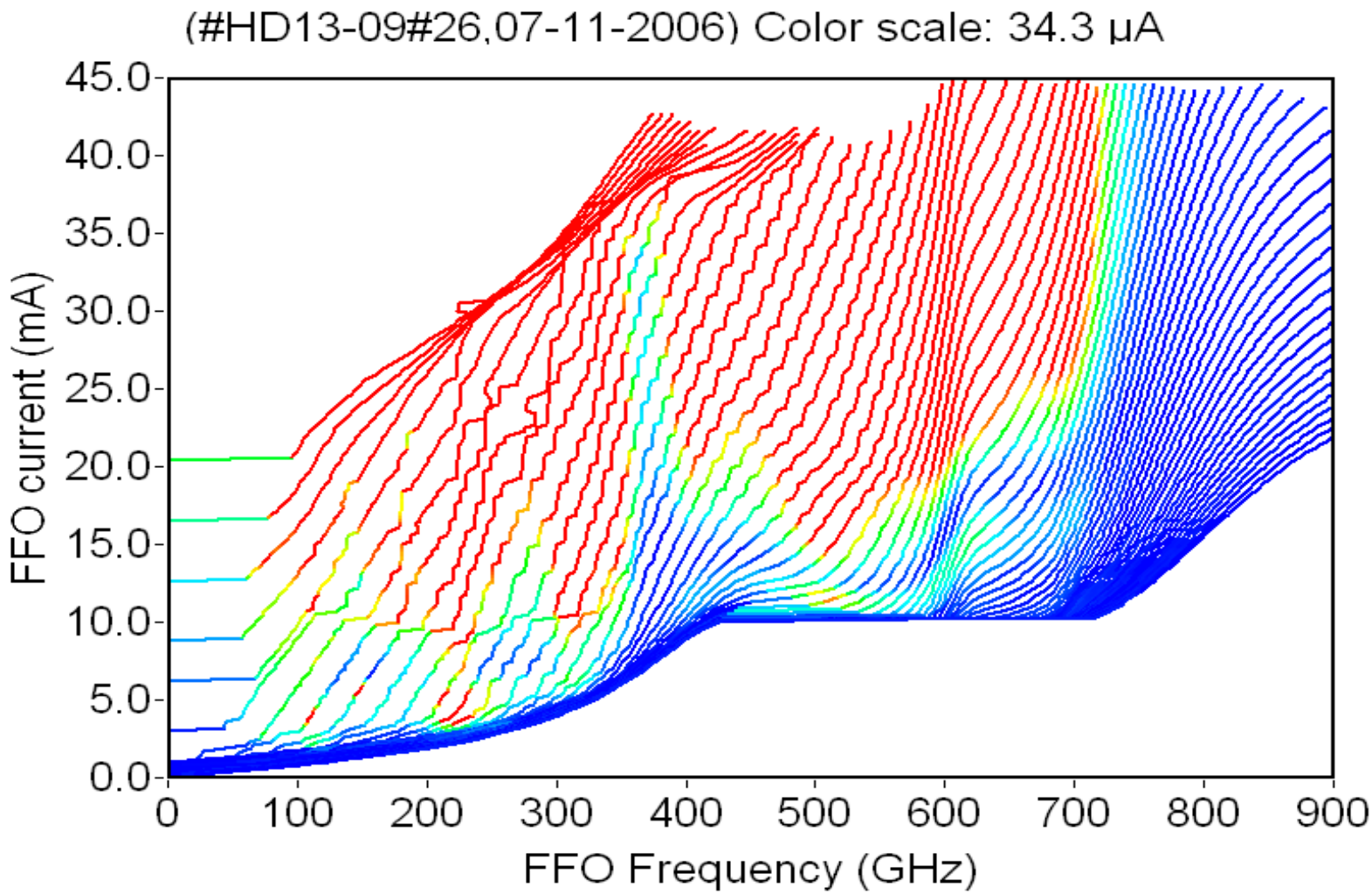


IV characteristic of Nb-AlN-NbN junction

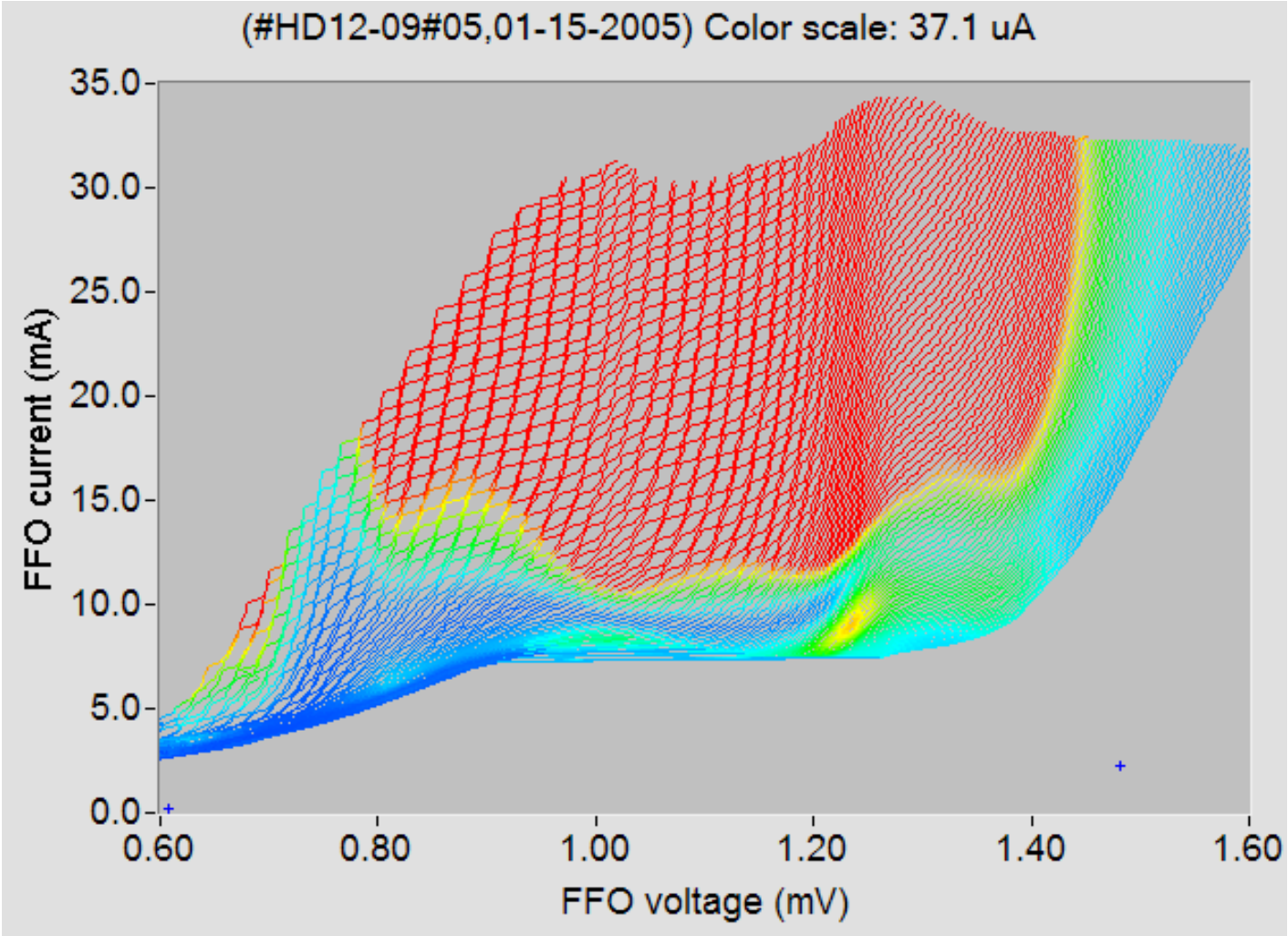
S= 2 μm², R_nS = 37 Ω μm², Jc= 6.5 kA/cm², Ic = 0



IVCs of the Nb-AlN-NbN-Nb FFO measured at different magnetic fields



Nb-AlN-NbN SIR – new features



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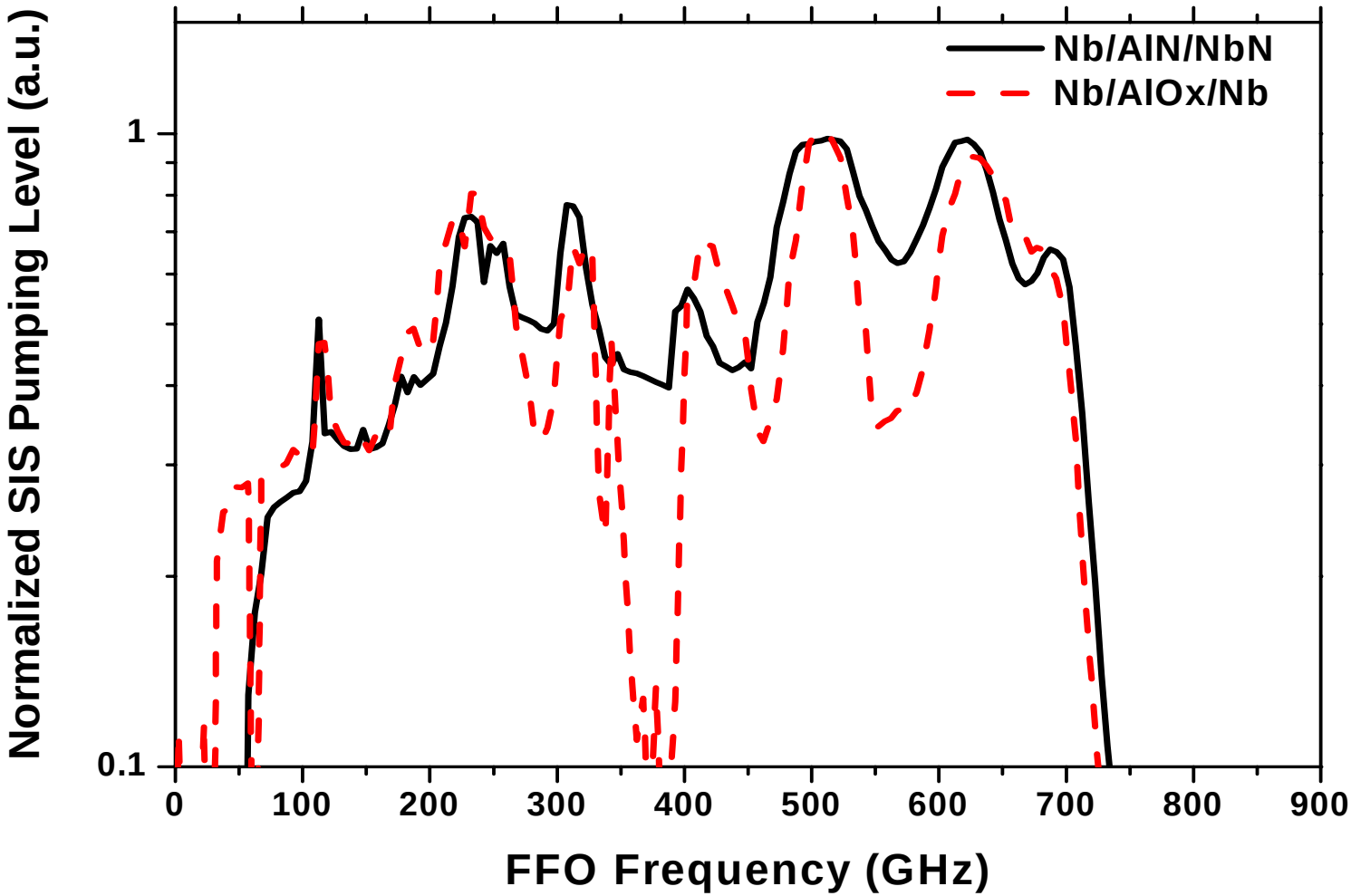
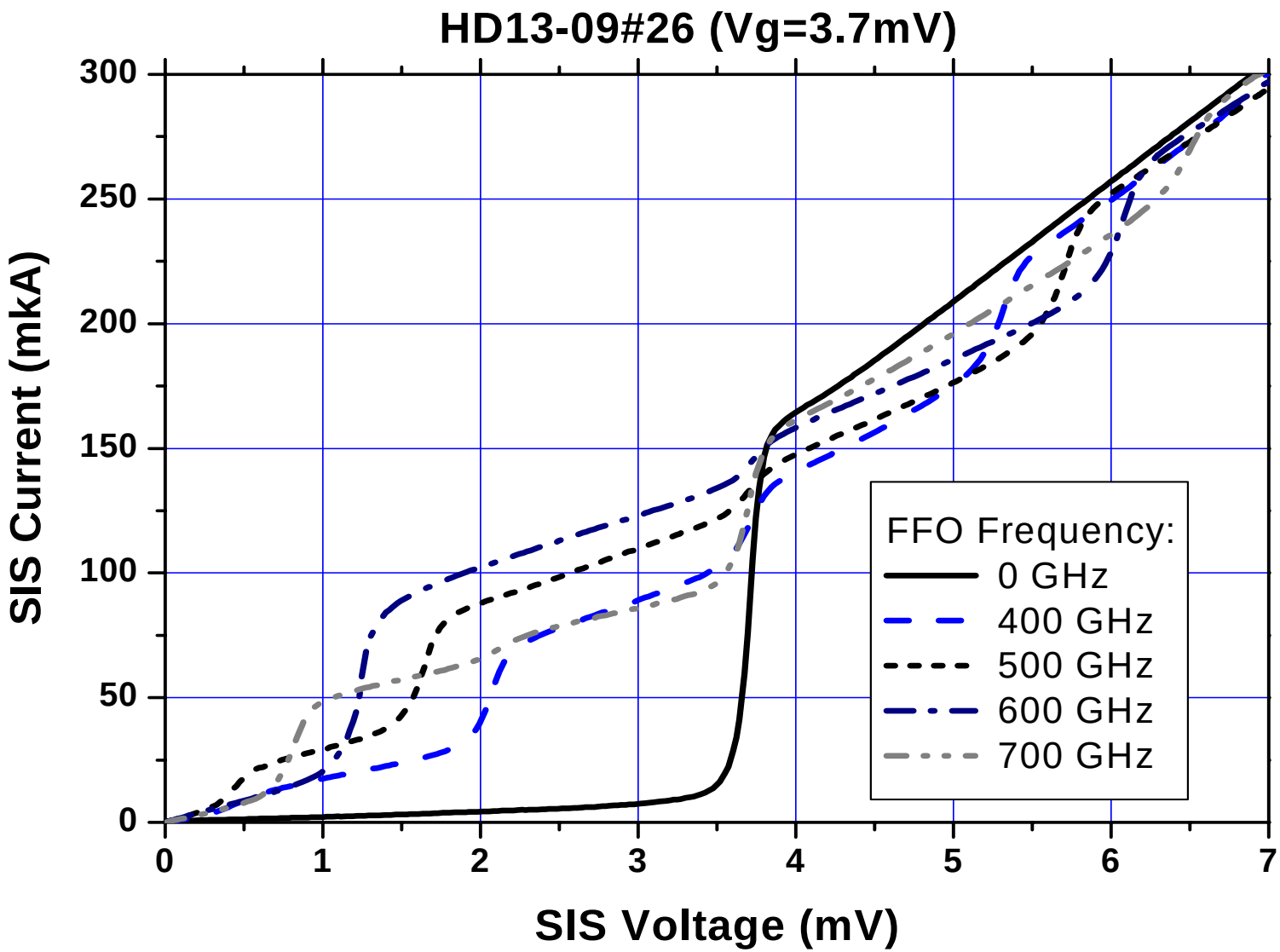
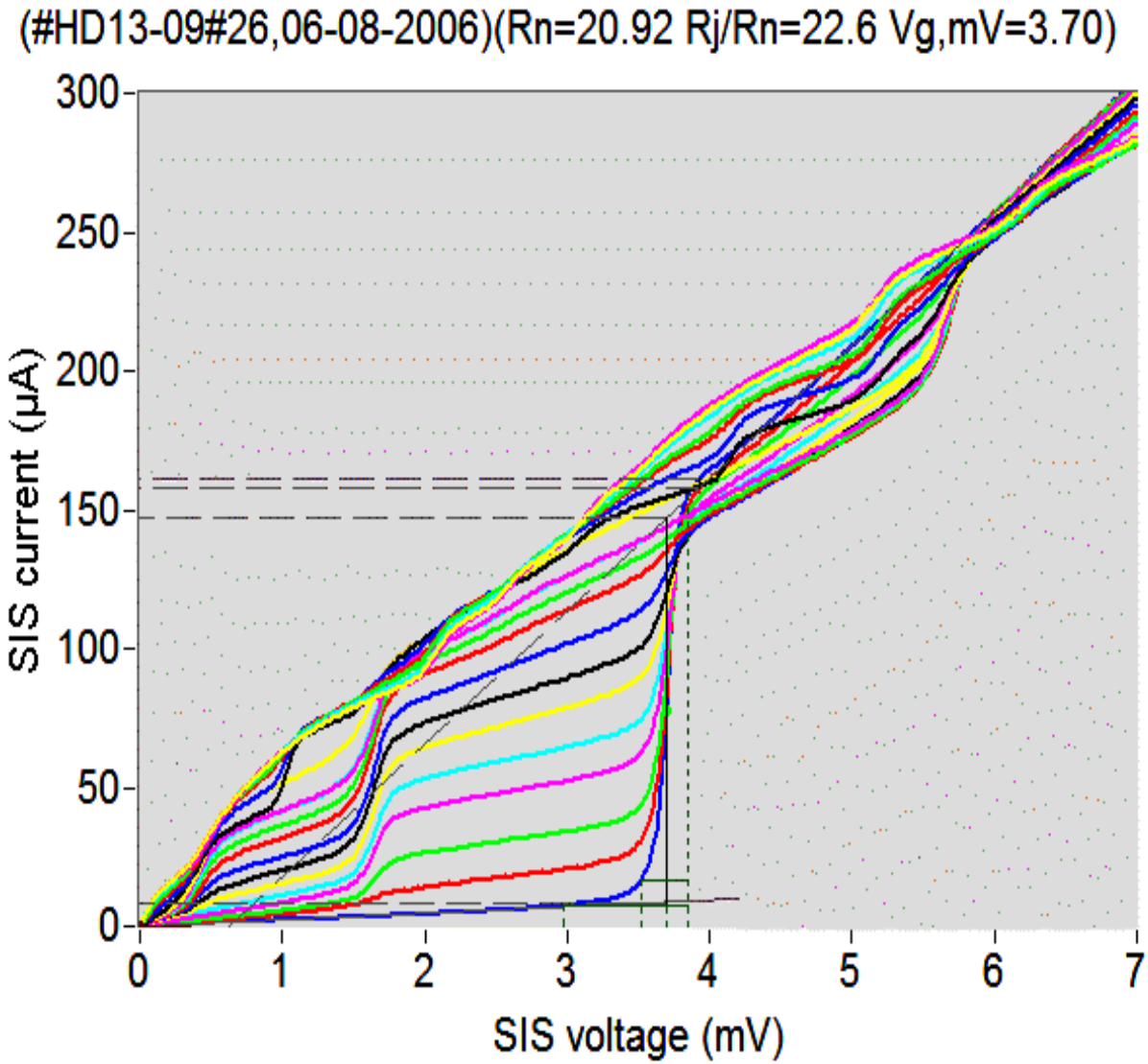
Maximum current detected by HM at V = 2.5 mV normalized on the current rise at Vg



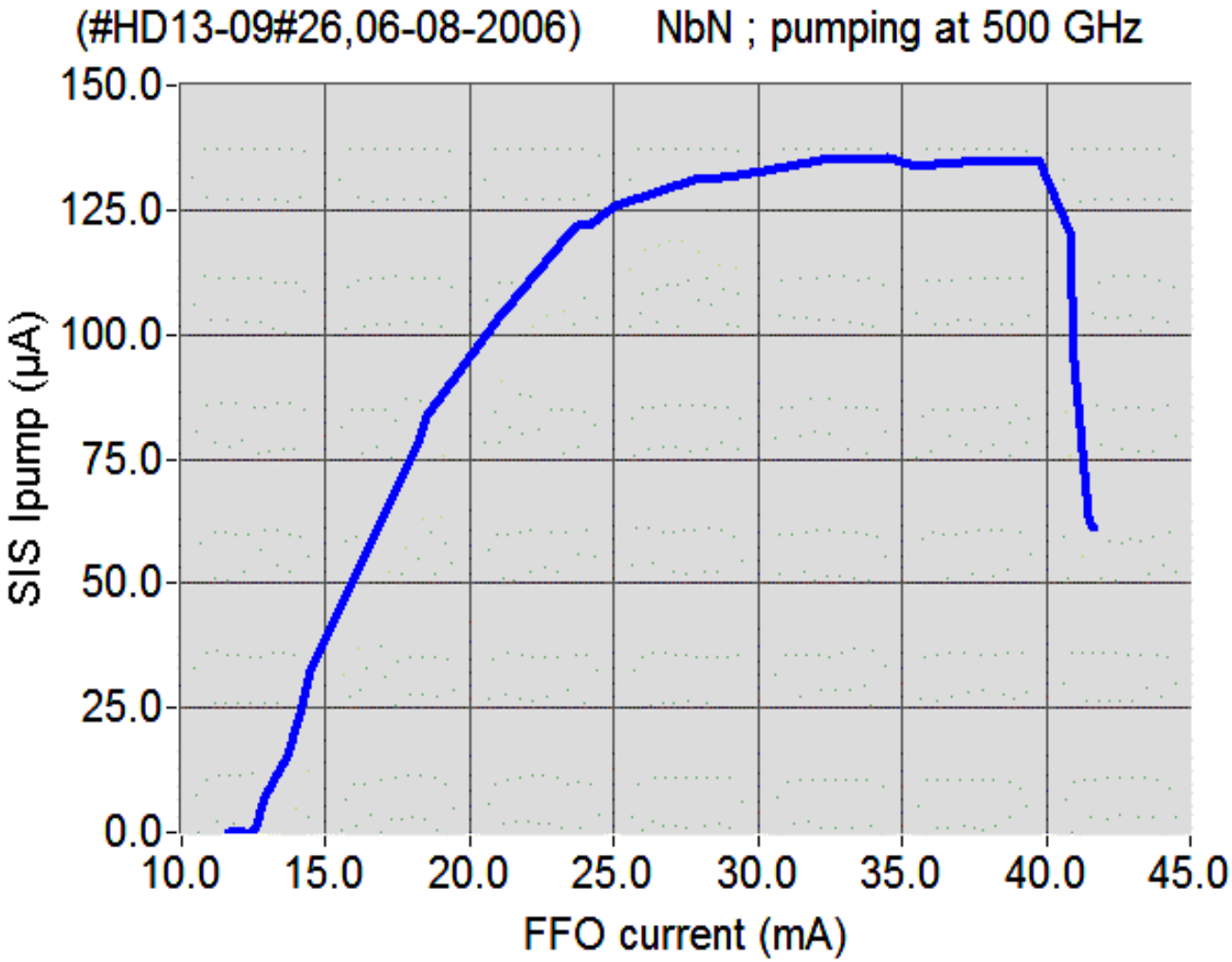
IVC of an SIS mixer pumped by FFO



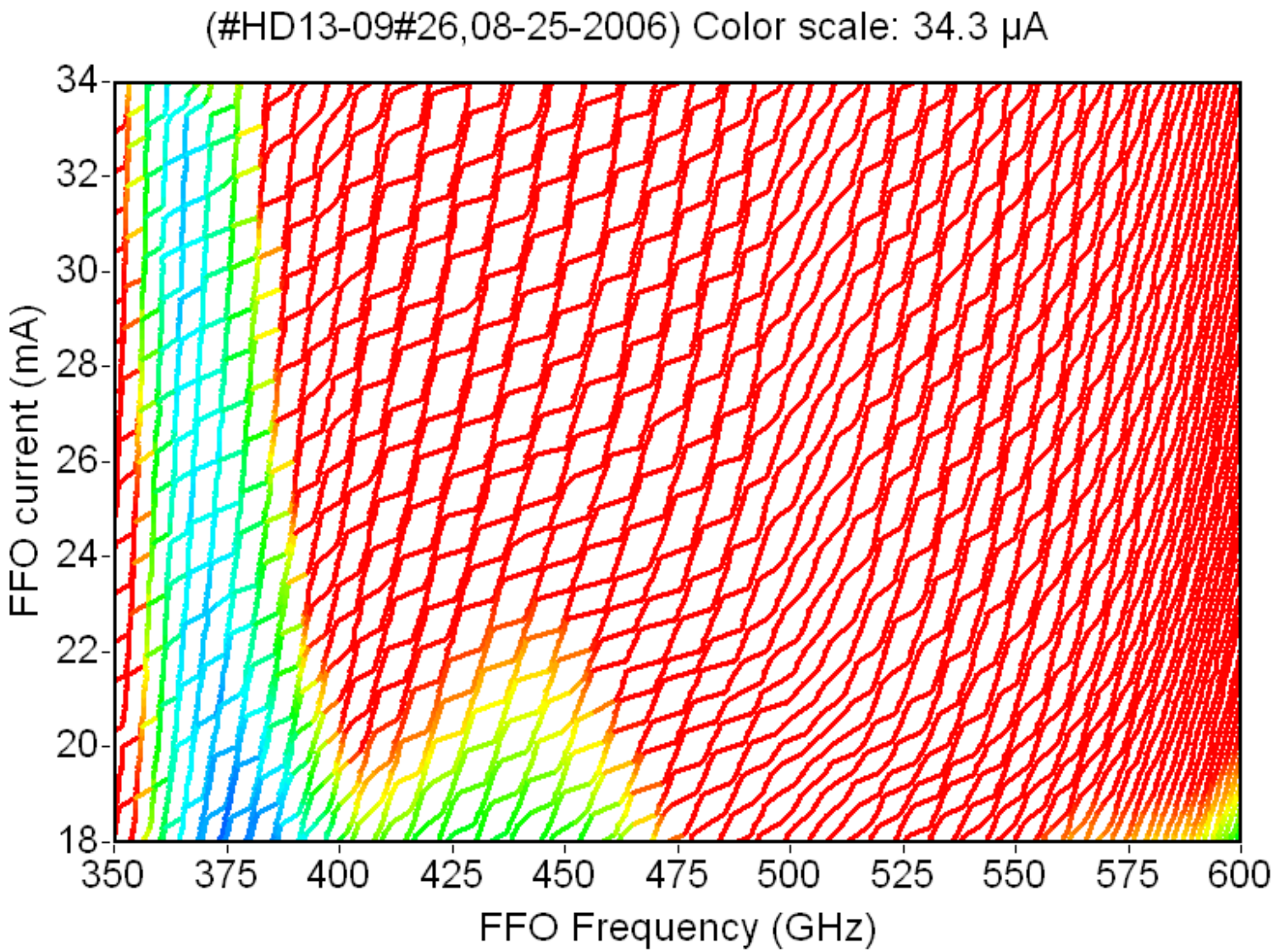
A set of SIS IV-curves, pumped by FFO at 500 GHz



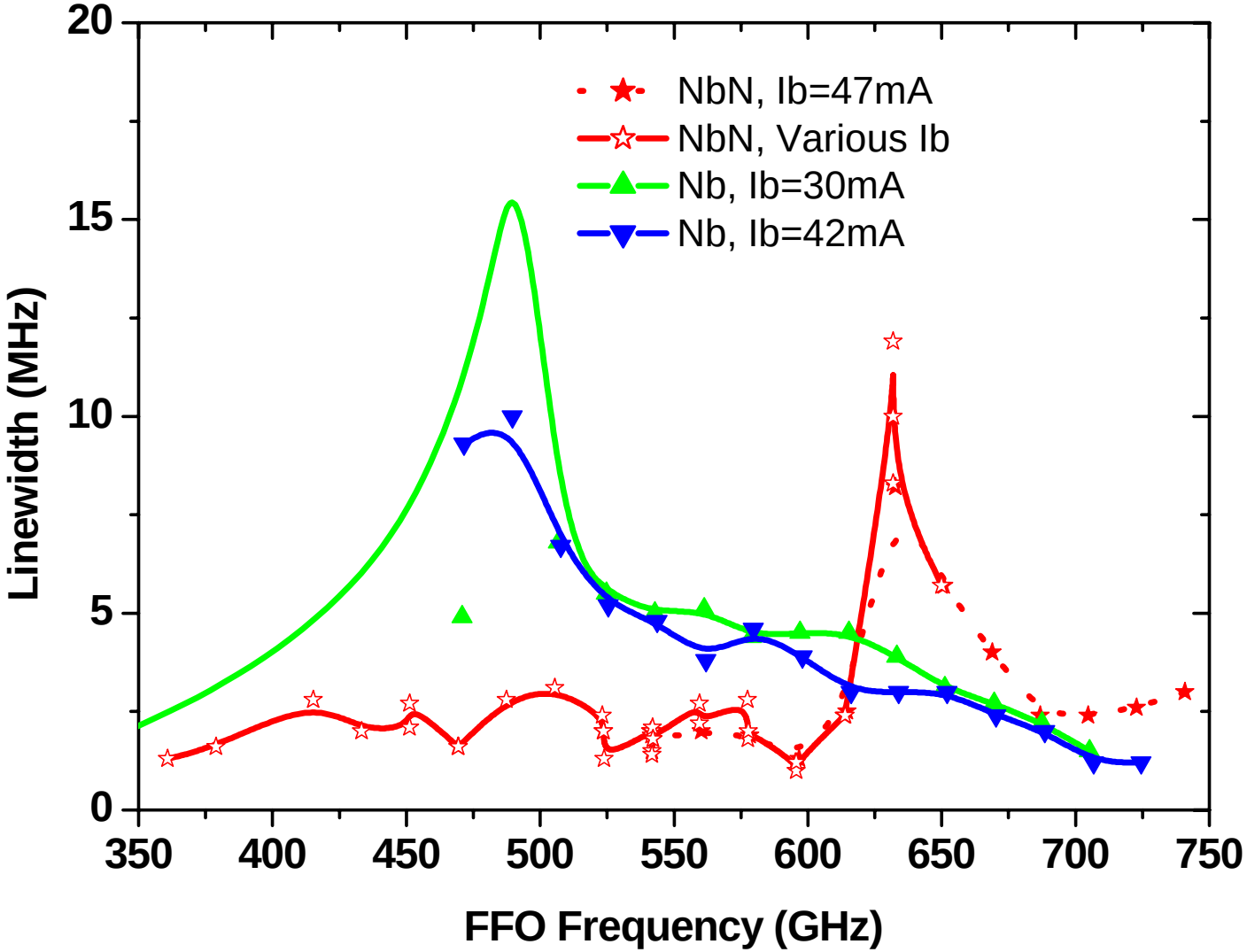
SIS mixer pumping at different Nb-AlN-NbN FFO bias (output power) setting



A close-up of FFO IVC in Fiske steps region



Nb-AlN-NbN circuits: LW on frequency



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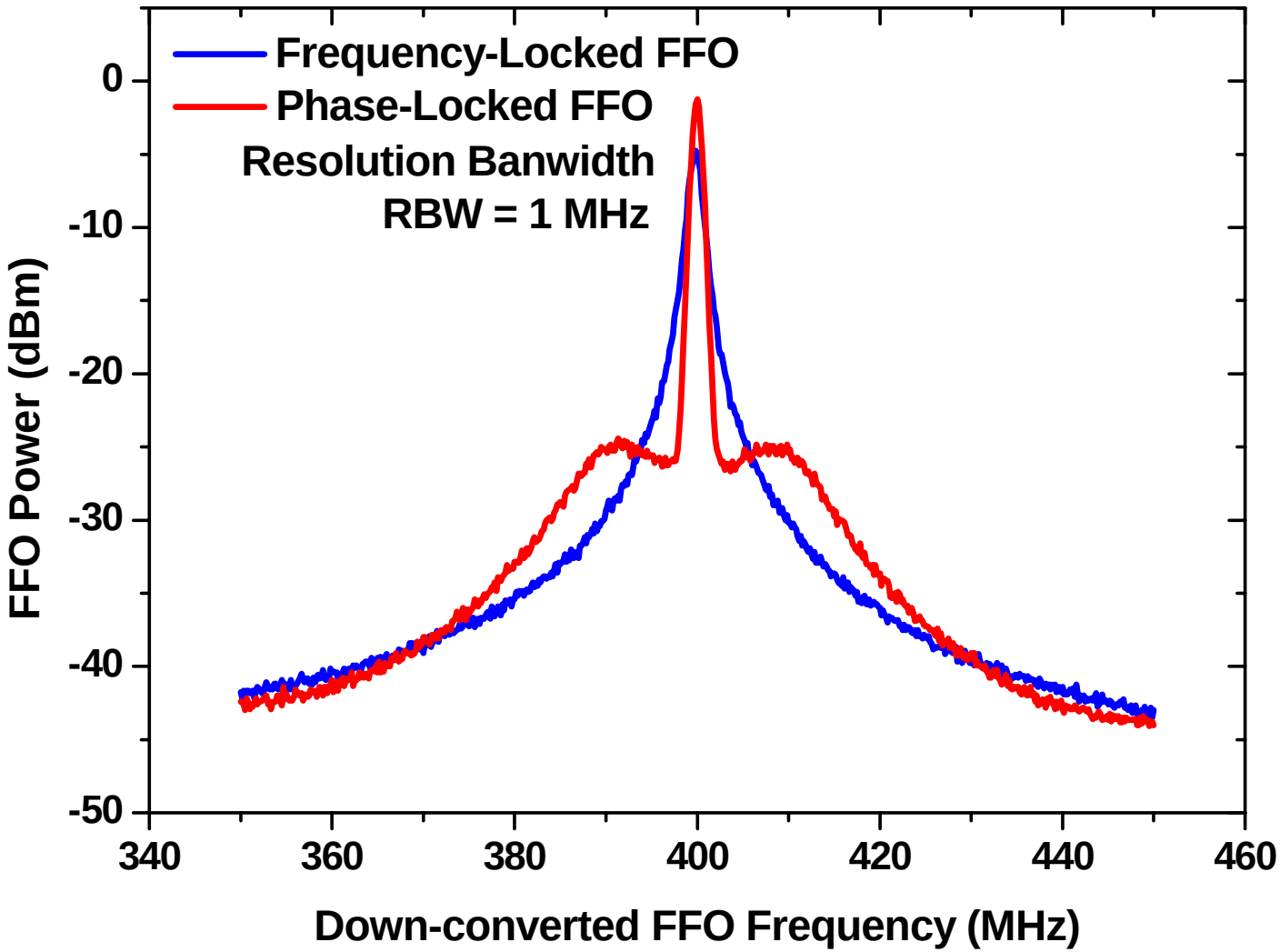
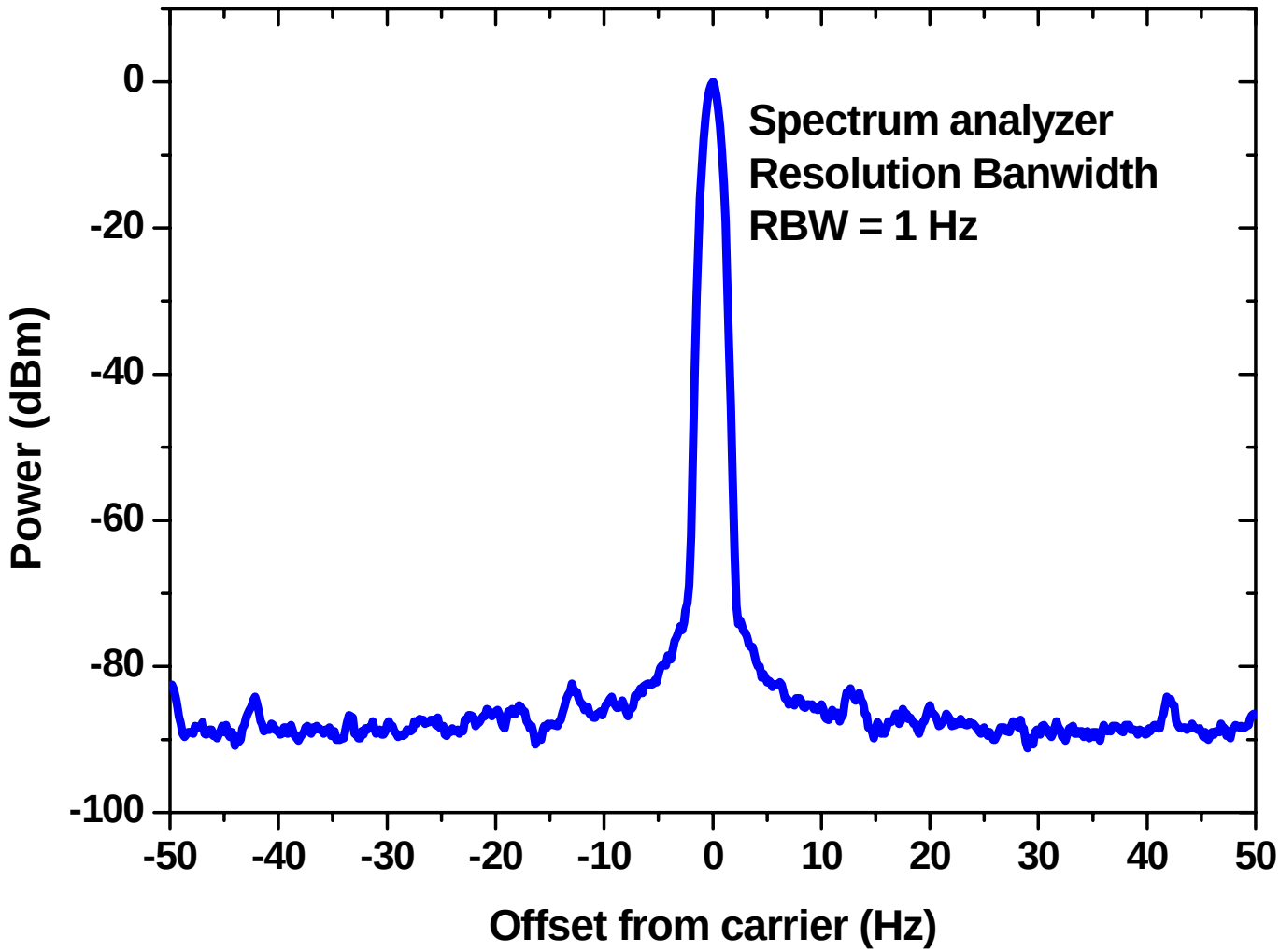
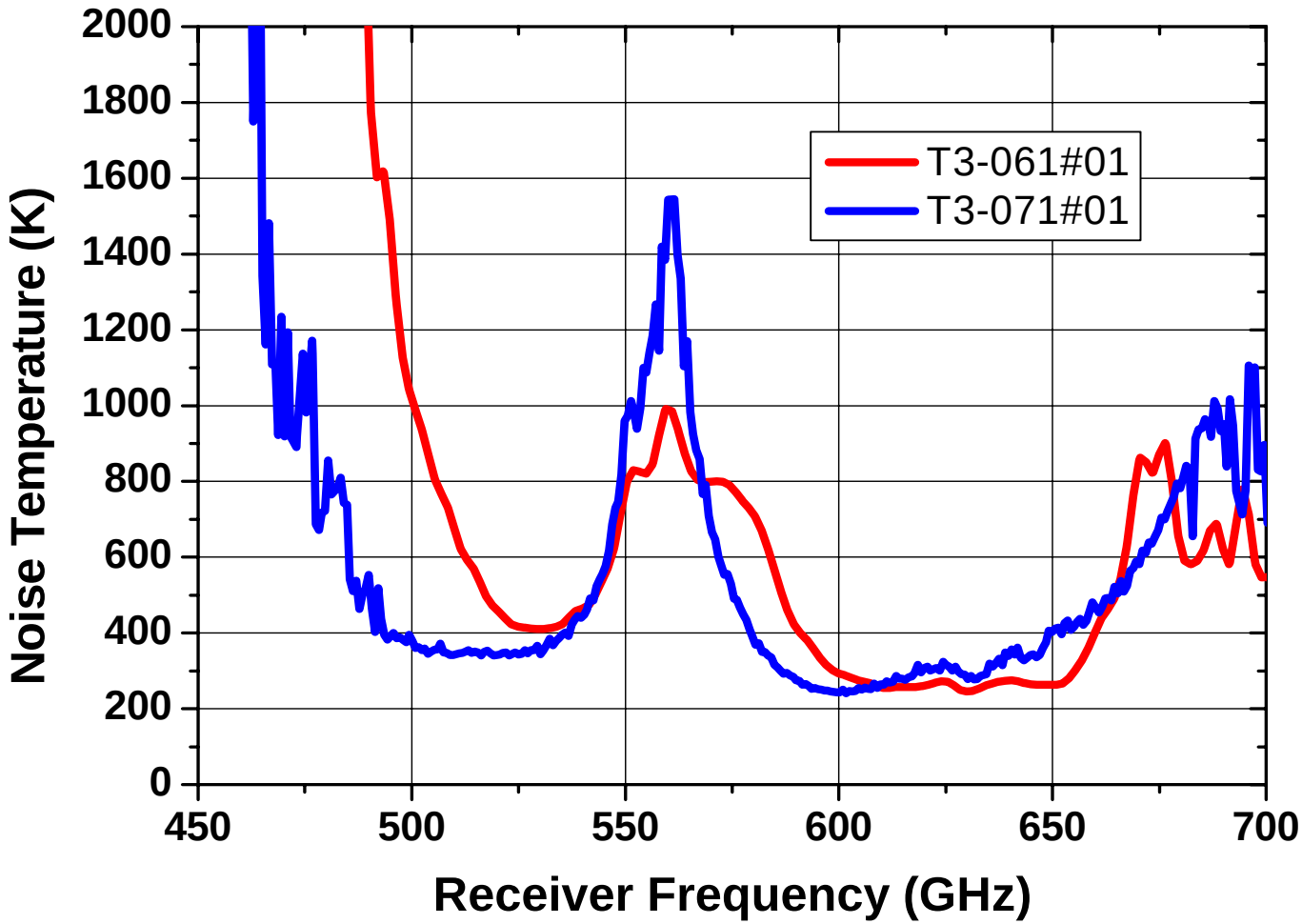
Down-converted spectra of the FFO operating at 671 GHz



Down-converted spectra of the FFO operating at 671 GHz. Span – 100 Hz.



Nb-AlN-NbN SIR: Tn on FFO frequency



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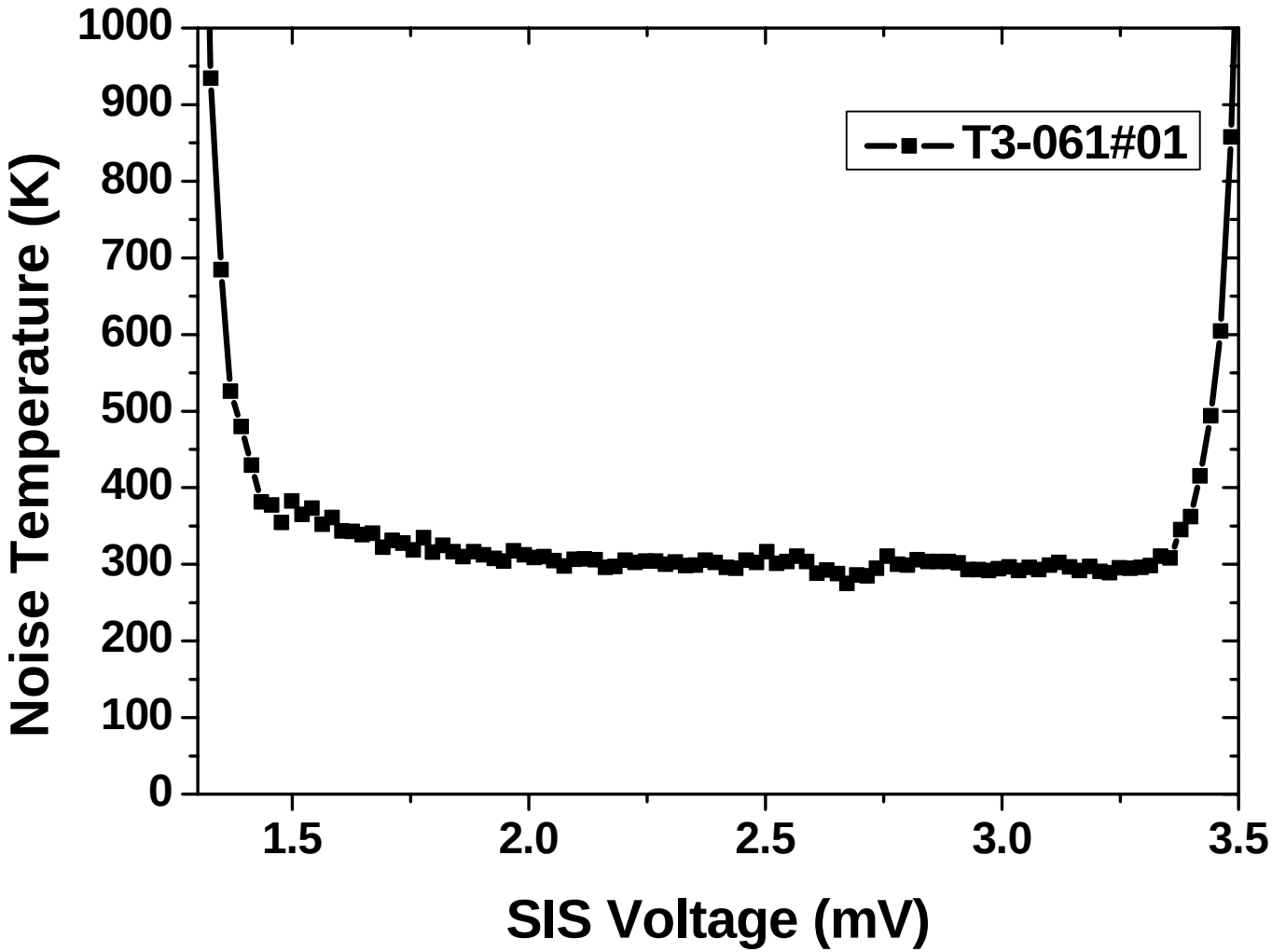
Nb-AlN-NbN-Nb SIR: Noise temperature on SIS bias voltage



Beam pattern of Nb-AlN-NbN-Nb SIR